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Title:

Discharged filtrate movement in food materials under application of electrokinetics

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Abstract

Orange juice (OJ) and malt extract (ME) samples were treated using an electrokinetic (EK) application to investigate the impact of the pH/Lowest conductivity point (LCP) ratio of experimental materials on the water profile direction and the anolyte to catholyte filtrate ratio. After applying the electric field through samples between two electrodes, filtrate was discharged mainly towards the anode in OJ samples (acidic medium, $\text{pH/LCP} < 1$) and towards the cathode in ME samples (alkaline medium, $\text{pH/LCP} > 1$). Adjusting the orientation of electrodes depending on the results maximised dewatering efficiency under EK by 7.8% in OJ and 11.8% in ME. Changing the pH/LCP ratio by adjusting the starting pH improved dewatering efficiency under EK by 25.7%. The results are used to develop theoretical guidelines to help determine the water profile direction and filtrate outlets for different food materials based on their pH and LCP values. EK is an effective method for dewatering food materials.

Keywords

Electrokinetics; dewatering; food drying; discharged filtrate

Abbreviations

A/C ratio: anolyte to catholyte ratio

EK: electrokinetic

IEP: iso-electric point

LCP: lowest conductivity point;

OJ: orange juice

ME: malt extract

NEC: net electrical charge

WPD: water profile direction

1. Introduction

Applying an electric field to a charged liquid or semi-liquid material using two electrodes results in several processes occurring at different components within the material: charged liquid ions, charged liquid particles and the liquid itself (Aziz, Dixon, Usher & Scales, 2006).

The combined effect of motion and electrical phenomena is commonly referred to as electrokinetics. These phenomena cause a movement of the different components towards one of the electrodes according to the process, the ion number and the charge (+ve or -ve) (Hunter, 1993; Aziz et al., 2006). For example, the movement of charged particles in an aqueous medium to an electrode of opposite polarity is known as electrophoresis (Weber & Stahl, 2002; Lockhart, 1981) which has been used in various applications, such as determining a particle's charge and separating enzymes and proteins. The second type of movement, electro-osmosis, is defined as the displacement of liquid relative to the medium under the influence of an electric field (Weber & Stahl, 2002; Lockhart, 1981). These two processes are used to enhance solid-liquid separation. There is another type of movement under electrokinetics which is produced by the same mechanism as electrophoresis but at the liquid level and works in the opposite direction to the charged ions that move to the opposite polarity electrode under electrophoresis (Aziz et al. 2006).

The benefits of electrokinetic (EK) applications in the area of dewatering were first reported in the mid-1970s by Yukawa, Yoshida, Kobayashi & Hakoda (1976, 1978). Other researchers continued working on the electro-osmotic and EK application in the area of dewatering such as removing heavy metal contaminants from soil by using an electric field in groundwater (Grundl & Michalski, 1996; Shapiro & Probstein, 1993), enhancing the ultra-filtration process (Zumbusch, Kulcke & Brunner, 1998), and minimising the radioactive nucleotides level in radioactive materials (Turner & Dell, 1984a, 1984b).

The operational parameters of these processes have been also investigated, such as the use of voltage and constant current conditions (Yukawa et al., 1976; Yukawa et al., 1978; Yoshida, Shinkawa & Yukawa, 1980) as well as salt concentration, conductivity, ionic strength, suspension types, electrode material, intermittent current application and the effect of voltage (Aziz et al., 2006).

Despite a fair amount of research on the potential use of an electrical field to improve dewatering of suspensions, the operational examples of their industrial use appear to be

74 remarkably few and most of the research has been done in the soil, waste and mining areas.
75 This is not because of the failure of the technology but due to control and operational
76 difficulties. Advancement in the field of geosynthetics and general material corrosively
77 properties, has made this a viable option again.

78 In the food processing area, EK applications have been used mainly for analytical
79 procedures such as protein and enzyme separation; but their use at an industrial scale has
80 been minimal and the amount of research which has investigated the potential benefits and
81 application of the technology on foodstuffs has been limited and is mainly in the food waste
82 area where EK is used to improve the dewatering process to reduce the volume of the waste
83 (Schmitz, 2004). The use of EK as a low-cost option for dewatering of food by-products
84 such as fruit peelings was reported more recently by Ng, Plunkett, Stojceska, Ainsworth et al.
85 (2011) who showed that the technique could be used to reduce the moisture content to around
86 70-80% in these waste products.

87 Applying an electric field between two electrodes to suspensions causes a movement of
88 the charged ions and particles towards one of the electrodes (the anode or the cathode)
89 according to their charge type under the influence of electrophoresis which in addition results
90 in water movement in the opposite direction. Negative ions and negatively charged particles,
91 which are dissolved in water, move toward the positively charged anode and water then
92 moves in the opposite direction to the cathode; in the same way, positive ions and positively
93 charged particles move towards the negatively charged cathode and water moves in the
94 opposite direction towards the anode (Aziz et al., 2006).

95 Although electrokinetic phenomena cause movement of ions and water (discharged
96 filtrate) towards the two outlets, the discharged filtrate volumes at each outlet are not equal.
97 The percentage of water volume moving towards each electrode depends on overall charge of
98 the suspension, the net electrical charge (NEC). If the NEC is positive the direction of the
99 major volume of discharged filtrate is towards the anode as the positive ions move towards
100 the cathode. In contrast, if the NEC is negative the direction of the major volume of
101 discharged filtrate is towards the cathode.

102 The NEC of most food particles especially protein depends on the isoelectric point
103 (IEP) of the particle, which is the pH value at which a particle is electrically neutral and
104 carries no NEC, and the pH of the medium. The net surface charge is affected by the pH of
105 the liquid in which the particle is submerged (Prasad, 2012). At the IEP pH, the NEC on the

particle is 0, since negative and positive charges are equal. This pH value is very important in electrical food applications especially as the conductivity decreases when the total ion content decreases by becoming neutral.

In this study, different expressions are used to define fluid movements under application of EK. The direction of the major volume of discharged filtrate (or water) is the water profile direction (WPD), driving filtrate to the main outlet. When the sample NEC is positive the WPD is towards the anode and the main outlet filtrate is the anolyte; conversely when the NEC is negative the WPD is towards the cathode and the main outlet filtrate is the catholyte. The relative movements in either direction are expressed through the anolyte to catholyte ratio (A/C ratio); where the anolyte and catholyte refer to the electro-osmotic flows corresponding to the movement under the impact of the electrokinetic process and/or the applied pressure towards either the anode or the cathode respectively (Yang, Nakhla & Bassi, 2005).

Many of the previous studies which investigated these movements reported data on only one stream, mostly the catholyte. For example, Yuan & Weng (2003) reported only catholyte data during dewatering of municipal sludge cake and similarly Habibi (2004) also report the movement of liquid toward the cathode during EK dewatering of oily sludge from a crude oil storage tank. However, some other studies have investigated two streams such as Yang et al. (2005) who measured the two filtrates and found that applying EK to oily sludge increased both streams but resulted with unequal-weighted streams where the balance was in favour of the anolyte. Ng et al. (2011) also report data for both anode and cathode streams, but in this study the flow to the cathode was consistently higher than to the anode for all of the food by-products tested.

1.1. Aims of Study

This research aimed to investigate the movement of the discharged liquid under the impact of EK represented by WPD as the main direction and A/C ratio as the ratio of the discharged liquid volume out flow at each electrode. The objective was to develop theoretical guidelines for designing and setting up the rigs needed to apply EK by determining the main fluid outlet according to the chemical properties of the foodstuff.

2. Materials and experimental method

2.1. Orange Juice (OJ)

A commercial orange juice (OJ) was purchased fresh for use in the experiments. Labelling indicated that the juice contained 16 orange fruits per 1 litre orange juice. The water content was 86.1% and the initial pH was 3.6.

2.2. Malt Extract (ME)

Malt extract (ME) samples were supplied by Muntons plc (Stowmarket, Suffolk, UK) as dark dry malt then prepared in the laboratory to produce a ME with a water content around 80%, using the following method: Dark malt grain was dispensed into water at 52°C (1 part grain: 4 parts water) and stirred with a paddle mixer at 9 rpm at 52°C for 20min. Then the contents were heated to 65°C, the stirrer speed was increased to 18 rpm and held at this condition for 20min; the temperature was then raised to 89°C, and the stirring speed further increased to 36 rpm for 20min. After this time the sample was allowed to cool down and was kept in refridgerated at 4°C for a maximum of 24 hours before analysis.

2.3. Experimental rig

A series of bench-scale experiments were conducted in the EK dewatering cell shown in Figure 1. The experimental rig was developed by modifying the ‘Rosli cell’ described by Jones, Lamont-Black, Glendinning & Pugh (2005), used to test the effects of EK on dehydrating water from soil. This cell was modified and redesigned taking into account the differences between the soil and foodstuffs in terms of physical (dry matter and viscosity) and chemical properties (composition, acidity and gas production).

The dimensions of the cell were OD = ~200mm, 4mm wall thickness and 500mm length, creating a sample tube with a capacity of up to 4 litres. The cell tube was made of acrylic while other parts were made of nylon. The electrodes were pierced disks of titanium. Two pieces of filter paper (0.2µm or 1µm according to the experiment, Whatman, Sigma-Aldrich Company Ltd, Dorset, England) were attached to the inner sides of the anode and cathode to retain solids.

The top electrode was held by a removable top cap, while the bottom electrode was held on the top of a vertical movable piston moved using a gas actuator (ISO Cylinder 80 x 300 mm, Buckinghamshire, UK, MK8 0AN) providing a pressure up to 6bar. Electrodes were connected to a controllable power supply (U8002A DC Power Supply, Agilent, 0-30V, 5A, West Yorkshire, UK, WF12 7TH).

2.4. Analytical methods

For a typical arrangement in the laboratory process, the electrodes were arranged horizontally; the charges of the top and bottom electrodes (anode or cathode) were chosen according to the experiment and sample material (as the WPD was different according to the food material due to the difference between the initial chemical properties of the products). The following orientations were used (Figure 2):

Normal: Anode at bottom, cathode at top

Reversed: Cathode at bottom, anode at top

Control: EK turned off

To determine the WPD and the optimum orientation of OJ and ME, experiments were run on 1L of each foodstuff at 30V and 4bar, and one of two pores sizes of filters (0.2 μ m or 1 μ m) as shown in Table 1.

The weights of anolyte and the catholyte filtrates were measured every 30 minutes and the filtrate pooled for each electrode using a sensitive electronic bench scale platform (Mettler Toledo PBA655/PBA655X, supplied by Northern Balance Ltd., Gateshead, UK) which was connected to Microsoft Office Excel 2003 through WinCT (RsCom / RsKey / RsWeight by A&D Company Ltd). The values of the total filtrate weight and dewatering efficiency (total and net) were compared and the A/C ratio used to show the WPD, to identify the main outlet, and to estimate the intensity of the EK effect. The pH of the filtrates was monitored throughout each experiment using a standard pH meter (Martini Instruments Mi 150 supplied by Milwaukee Electronics Kft., Szeged, Hungary); the meter was calibrated daily using calibration standards (pH4, pH7 & pH10) before use.

The lowest conductivity point (LCP) was used in this study instead of IEP due to the difficulty of measuring the IEP of the food samples. LCP for the initial OJ and ME samples was determined by titration of the samples with 10% (w/v) NaOH and 10% (v/v) HCl to adjust the pH of the samples to between 1.5 and 6.0. Conductivity at each pH was determined using a conductivity meter (Jenway 4510 supplied by Bibby Scientific Ltd., Stone, UK).

The effect of changing the initial pH of the OJ was investigated by adjusting the pH of the juice to pH 1.5, 5.0 and 6.5 and then applying EK to the samples at 30V, 4bar with a 1 μ m filter in comparison with the fresh juice (pH 3.6).

198 *2.5. Statistical Analysis*

199 Results are presented as means \pm standard deviation (SD). Significance of differences
200 between means was determined by analysis of variance and considered significant if $p < 0.05$
201 using Minitab 16 Statistical Software (Minitab Inc., PA, USA).

3. Results

For both OJ and ME the discharge filtrate moved almost equally to the two outlets when EK was not applied under the Control conditions due to the equal pressure at both outlets and the lack of electric field to drive ions to each electrode (Table 1). The small increase in the bottom outlet is likely to be due to the additional impact of gravity. When the EK field was switched on, the difference in between the two outlets increased and the A/C ratio was >1 for OJ and <1 for ME. For OJ, therefore, the dominant WPD was in the direction of the anode whereas for ME the WPD was towards the cathode even when the electrodes were reversed showing that the discharge filtrate was determined by the electrode charge not the electrode position. An example of the profile of filtrate production for OJ (panel A) and ME (panel B) is shown in Figure 3.

Figure 4 shows the effect of pH on the conductivity of the food samples. The LCP was at pH 3.2 for the ME and pH 4.0 for OJ. Changing the initial pH of the OJ had an impact on discharge. At pH values $<$ LCP the A/C ratio was >1 indicating greater output at the anode but when the pH was raised above the LCP the A/C ratio was <1 indicating greater discharge at the cathode under the same EK conditions (Table 1).

The total dewatering efficiency (TDE) was calculated as the ratio of the total filtrate weight to the initial weight of water in the sample; the initial moisture content was 86% for OJ and 80% for ME. Net dewatering efficiency (NDE) was calculated as the difference between TDE under EK and TDE for Control (Table 1). EK improved NDE by 7.8% with OJ in the Normal orientation and by between approximately 5 and 12% under optimal conditions with ME, but reduced dewatering when the electrodes were in the opposite orientation.

4. Discussion

Some previous studies have investigated water movements in non-food materials under the application of EK and observed only one stream (mostly the catholyte) which was affected by the properties of the samples investigated. Fourie et al. (2007), for instance, used an applied electric field to dewater mineral sands tailings (kaolinite and quartz) with a pH value of 6.4. The IEP of kaolinite varies between 3.3 and 5 (Brian & Garrison, 1997). This basic medium ($\text{pH} > \text{IEP}$) causes water to move toward the cathode, which was the basis for using six anodes in the test tank to push the water towards the single cathode extracting outlet. Lamont-Black et al. (2007) also applied EK on three types of thickened kimberlite slimes from diamond mines in southern Africa with pH values of between 7.88 and 9.53. The test equipment used an irrigated anode (bottom electrode) and an open-draining cathode (top electrode). Finally, Aziz et al. (2006) used an alkaline suspension ($\text{pH} = 10$) and collected the outflow at the cathode, which also acted as a permeable medium.

In contrast, Yang et al. (2005) used oily sludge ($\text{pH} 5.3 - 5.6$, $\text{IEP} 5.9$) and experienced outlet streams at both electrodes but with a higher electro-osmotic flow towards the anode since in this case $\text{pH} < \text{IEP}$ and positive charges on sludge particles predominated. Yang et al. (2005) focused on the two flows reporting their volumes different applied voltage conditions. Studies on the use of EK as a low-cost method for reducing the water content of either whole foods or food waste by-products have been limited. Ng et al. (2011) dewatered food by-products which were all acidic (range $\text{pH} 6.4$ to 3.7) and demonstrated higher outflow from the anode for all of the products tested. The effluent discharged at the anode for each product had a lower pH than that produced at the cathode and this was dependent on the voltage applied across the cell. The results presented here support these observations and suggest that the method could be applied to foodstuffs such as OJ which have a relatively high water content. The advantages of using this method rather than using heating methods in potentially preserving heat-sensitive nutrients such as vitamins is an area which warrants further investigation.

Thus WPD depends on the net charge of the suspension; when the net charge is positive ($\text{pH} < \text{IEP}$), the positive ion content is higher than the negative ion content and the ion movement is towards the cathode under electrophoresis while the WPD is in the opposite direction under EK towards the anode and the A/C ratio is >1 , while it is toward the cathode when the net charge is negative ($\text{pH} > \text{IEP}$) and the A/C ratio is <1 . This was demonstrated in

this study (Table 1) where the WPD was expected to be towards the anode for OJ where $\text{pH}=3.6 < \text{LCP} = 4$, and towards the cathode for ME where the $\text{pH}=4.55 > \text{LCP} = 3.2$ when the EK was on. Under control conditions with no EK for both products the discharge filtrate moved almost equally towards both electrodes due to the pressure on both outlets. In each case, regardless of electrode orientation, the bottom outlet showed a small increase in discharge due to the additional impact of gravity confirming that under EK, WPD is related to the electrode charge not to the electrode position. These effects are summarised in Figure 3.

Net dewatering efficiency (NDE) was significantly affected by the electrode orientation, with opposite effects for the two products as predicted by their differing net charges (Table 1). Figure 3 shows that over time filtrate discharge rate decreased. This was due to caking of the product at the electrodes as dewatering progressed. EK had a positive effect on OJ in the normal orientation but a negative effect when the electrodes were reversed. In contrast, for ME, EK improved NDE under reversed conditions compared with the normal orientation.

Each food material has its own natural chemical properties, but adjusting the initial pH could play a positive role in improving the EK process. For non-food samples, Aziz et al. (2006) adjusted the sample pH to increase the alkalinity of the medium to pH 10 using sodium hydroxide, enhancing migration to the cathode. In the present study, adjusting the pH of OJ either above or below the LCP (~ 4 for OJ) impacted on dewatering efficiency with greater effects the further above or below the LCP (Table 1). This effect was due to the change in conductivity which was higher the further the pH from the LCP (Figure 4) as expected with the greater number of charged ions under these conditions.

For higher filtration yield and energy saving, gravity can be used to support the movement of the discharged liquid when EK is applied by designing the equipment with the WPD to the main outlet in line with gravity. The orientation of the anode and the cathode in the EK equipment must take into account the chemical properties of the foodstuff together with the impact of all forces that affect particle movement in such foodstuffs. In the current model, to concentrate foodstuffs in a vertical cell, two forces are used: (A) an electrical force generated by applying a voltage between two horizontal electrodes across the sample, and (B) a mechanical force generated by applying a pneumatic pressure ram. A small additional effect of gravity is evident in the vertical cell.

Figure 5 shows the electrode set-up and the forces that affect water movement under three orientations (Control, Normal and Reversed) and in two mediums (acidic $\text{pH} < \text{IEP/LCP}$) and basic $\text{pH} > \text{IEP/LCP}$). Where:

F_C : sum of the forces pushing particles to the cathode.

F_A : sum of the forces pushing particles to the anode.

P : Pressure.

g : Gravity.

EK_C : EK toward the cathode.

EK_A : EK toward the anode.

EK_T (Total EK) = $|EK_C - EK_A|$

Three differing scenarios are considered to explain the significance of these factors on WPD:

Case (1): Control, no EK

Water is influenced by the impact of pressure which pushes water equally toward both outlets and gravity which pushes water downwards.

$$F_{\text{Top}} = P - g$$

$$F_{\text{Bottom}} = P + g$$

WPD is almost equal toward both outlets with a small increase for the bottom outlet and Anolyte \approx Catholyte, A/C ratio ≈ 1 (Figure 5(A))

Case (2): EK is on and $\text{pH} < \text{IEP/LCP}$

This scenario is equivalent to using OJ. In addition to Control forces, water is influenced by the electric field which pushes water towards either the anode or the cathode determined by the ratio of the positive and negative ion content. Since the NEC is positive ($\text{pH} < \text{IEP/LCP}$), $EK_A > EK_C$ and the EK_T is towards the anode.

➤ WPD is toward the anode (the bottom in the Normal orientation and the top in the Reversed orientation) as the NEC is positive and ion movement is towards the cathode.

➤ Anolyte $>$ Catholyte \Rightarrow A/C ratio > 1

➤ Normal orientation (anode at the bottom) (Figure 5(B))

$$F_C = P - EK_T - g$$

$$F_A = P + EK_T + g$$

➤ Reversed orientation (cathode at the bottom) (Figure 5(C))

$$F_C = P - EK_T + g$$

$$F_A = P + EK_T - g$$

In this case the optimal orientation is the Normal position with the main outlet, the anolyte, at the bottom to combine the effects of EK, pressure and gravity.

Case (3): EK is on and $pH > IEP/LCP$

This scenario is equivalent to using ME. Since the NEC is negative ($pH > IEP/LCP$), $EK_A < EK_C$ and the EK_T is towards the cathode.

➤ WPD is toward the cathode (the top in the Normal orientation and the bottom in the Reversed orientation) as the NEC is negative and ion movement is toward the anode.

➤ Anolyte < Catholyte $\Rightarrow A/C$ ratio < 1

➤ Normal orientation (anode at the bottom) (Figure 5(D))

$$F_C = P + EK_T - g$$

$$F_A = P - EK_T + g$$

➤ Reversed orientation (cathode at the bottom) (Figure 5(E))

$$F_C = P + EK_T + g$$

$$F_A = P - EK_T - g$$

In this case the optimal orientation is the Reversed position with the main outlet, the catholyte, at the bottom to combine the effect of EK, pressure and gravity.

5. Conclusion

For the two food products tested, application of EK technology to enable dewatering was shown to be effective under a range of conditions. The starting pH and the IEP/LCP properties of the food materials were key determinants of dewatering efficiency and affected the WPD in each material. Controlling these factors and adjusting the orientation of electrodes to maximise dewatering efficiency under EK, pneumatic pressure and gravity is key to the future application of EK technologies in the food industry. EK technologies have the potential for low-cost dewatering of foodstuffs and warrant further investigation.

347 **Acknowledgements and conflicts of interest**

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Table 1. Filtrate parameters and dewatering efficiency under differing EK conditions for orange juice and malt extract

Experimental conditions	Anolyte (g)	Catholyte (g)	Total (g)	Anolyte (%)	Catholyte (%)	A/C ratio	Flow rate (g/min)	Total Dewatering efficiency (%)	Net Dewatering efficiency (%)
Set 1: Orange Juice, 1L, 30V, 4 bar, 0.2 µm filter, 5.5 hours									
Control ¹	239±7 (B)	222±4 (T)	461±11	51.9	48.1	1.08	1.40	59.6	
Normal ²	330±11	192±4	522±15	63.2	36.8	1.72	1.58	67.4	7.8
Reversed ³	193±6	116±3	309±9	62.5	37.5	1.67	0.93	39.9	-19.7
Set 2: Malt Extract, 1L, 30V, 4 bar, 1.0 µm filter, 3.5 hours									
Control	202±5 (B)	171±8 (T)	373±13	54.2	45.8	1.19	1.78	46.7	
Normal	139±4	188±6	327±9	42.6	57.4	0.74	1.56	40.9	-5.8
Reversed	221±5	247±6	467±11	47.2	52.8	0.89	2.22	57.4	11.8
Set 3: Malt Extract, 1L, 30V, 4 bar, 0.2 µm filter, 2 hours									
Control	80±6 (B)	77±4 (T)	158±9	51.0	48.9	1.04	1.32	19.8	
Normal	90±4	110±4	201±7	45.1	54.9	0.82	1.67	25.1	5.3
Reversed	99±3	122±7	220±9	44.8	55.2	0.81	1.84	27.5	7.8
pH-adjusted Set: Orange Juice, 1L, 30V, 4 bar, 0.2 µm filter, 3 hours									
Control	218±5	203±6	421±10	51.8	48.2	1.07	2.34	54.4	
pH 1.5	343±4	277±5	620±10	55.3	44.7	1.24	3.44	80.1	25.7
pH 3.6	263±4	202±6	465±10	56.5	43.5	1.30	2.58	60.0	5.6
pH 5.0	211±5	222±5	433±10	48.6	51.4	0.95	2.40	55.9	1.5
pH 6.5	243±3	327±4	569±7	42.6	57.4	0.74	3.16	73.5	19.1

¹Control, 0V, no EK application

²Normal, Cathode at the top (T) of the cell

³Reversed, Cathode at the bottom (B) of the cell

⁴In the control situation with no EK the filtrate appears at the bottom (B) or top (T) outlet

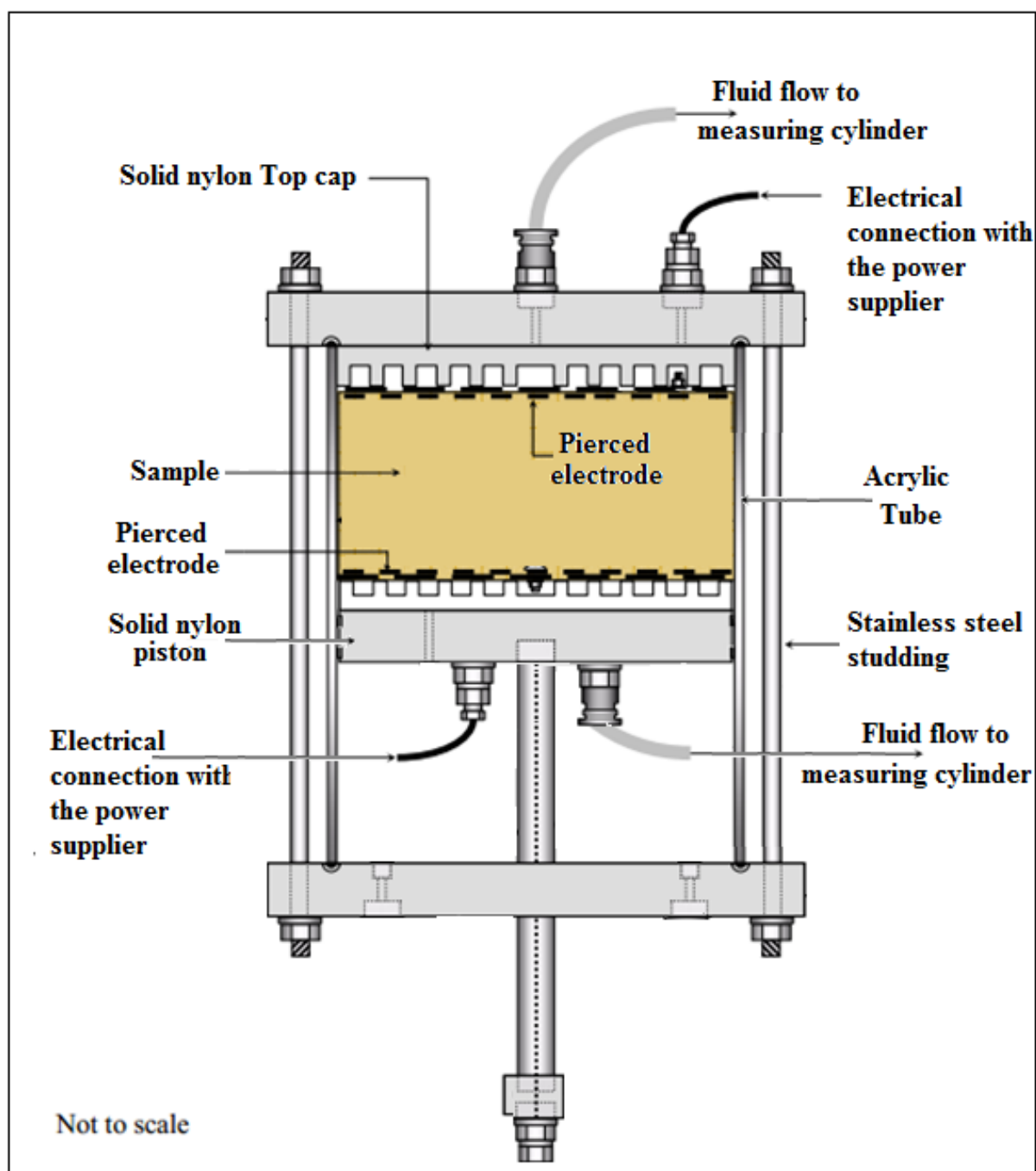


Figure 1. Electrokinetic dewatering cell, edited from Jones, Lamont-Black, Glendinning & Pugh (2005)

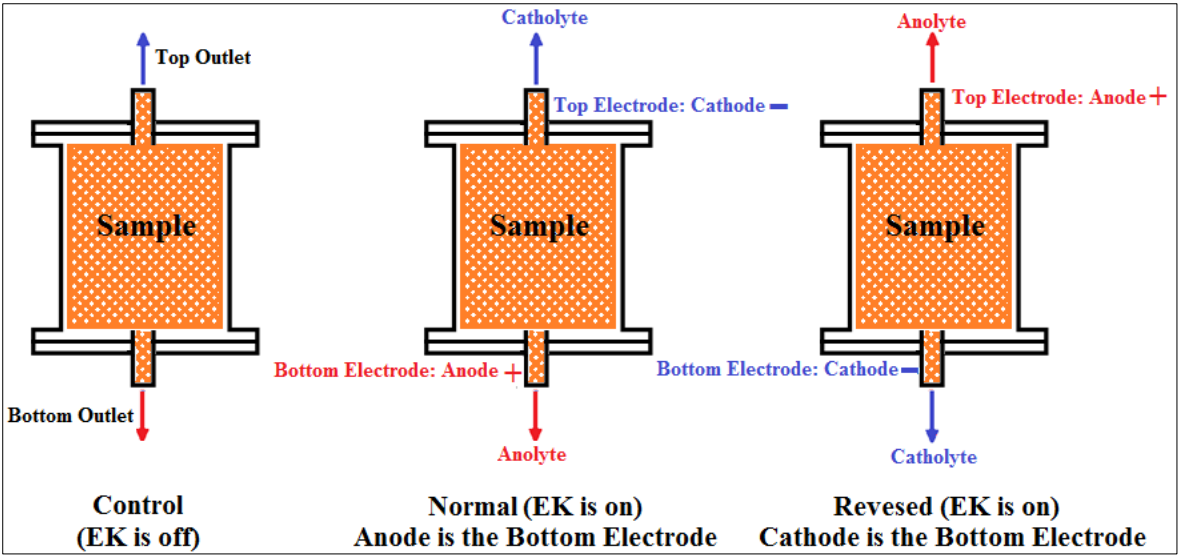


Figure 2. Specifications of the electrode orientation during Control, Normal and Reversed EK operation.

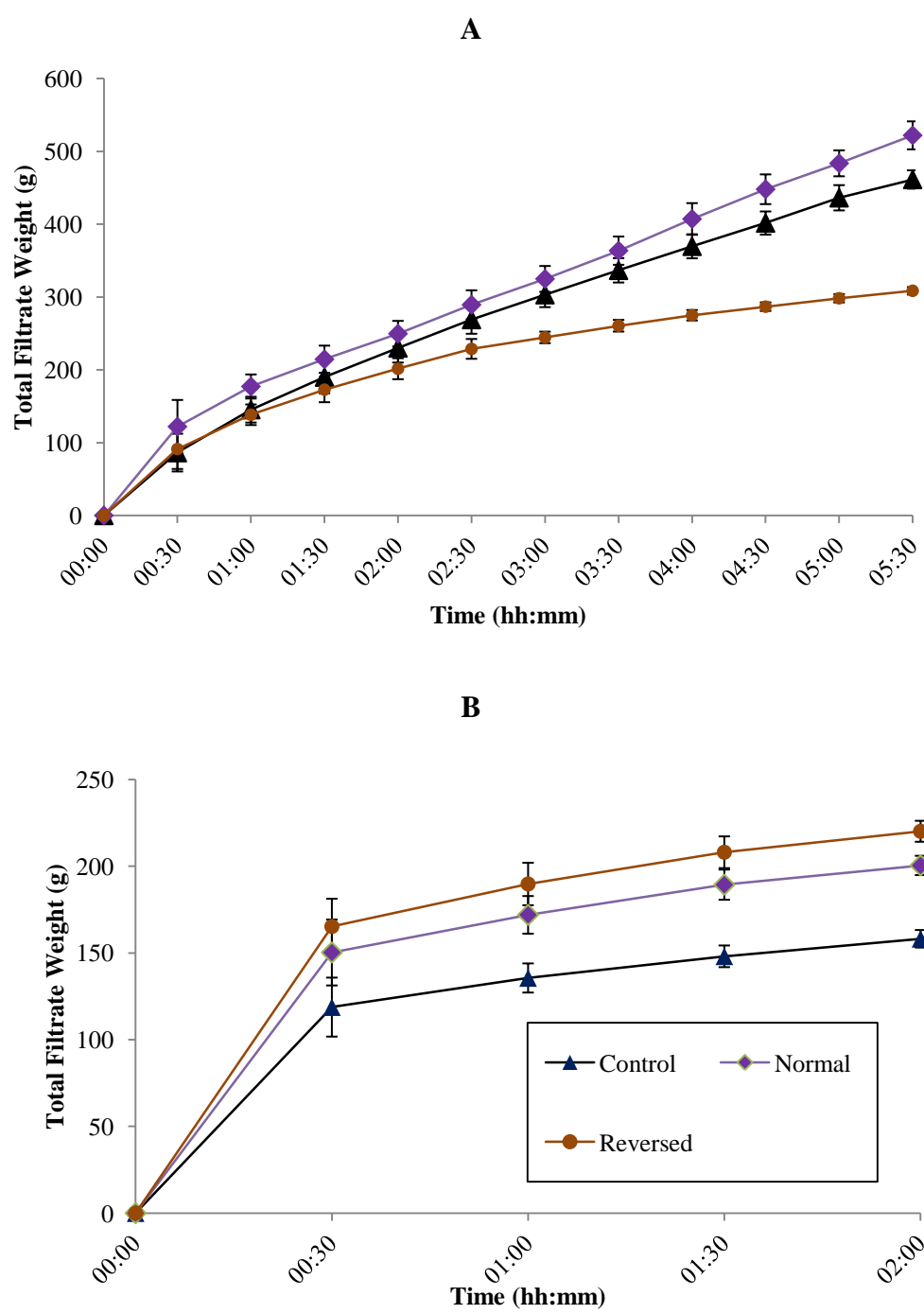


Figure 3. Profile of total filtrate output for orange juice (panel A) and malt extract (panel B) with 0.2 μ m filter. Control is no EK application, Normal is cathode at the top, Reversed is cathode at the bottom. Values are means \pm SD.

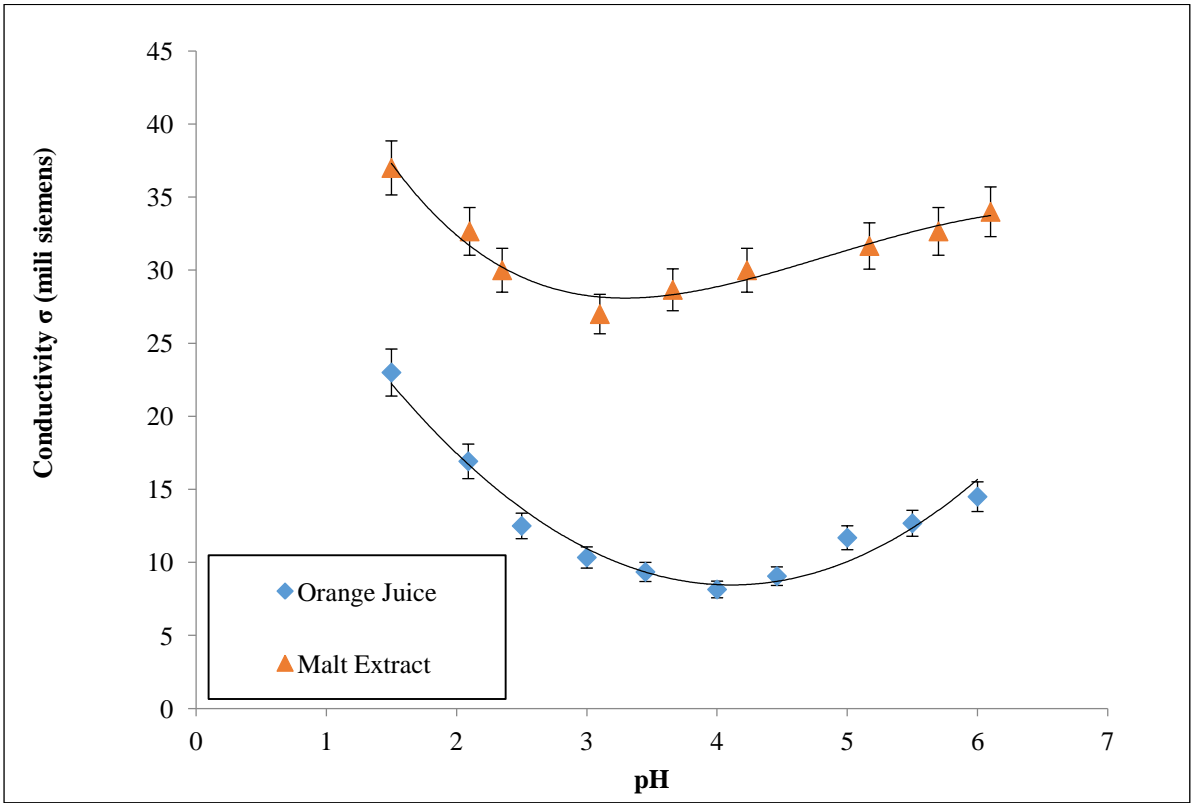


Figure 4. Change in conductivity of OJ and ME under different pH conditions. Values are means \pm SD

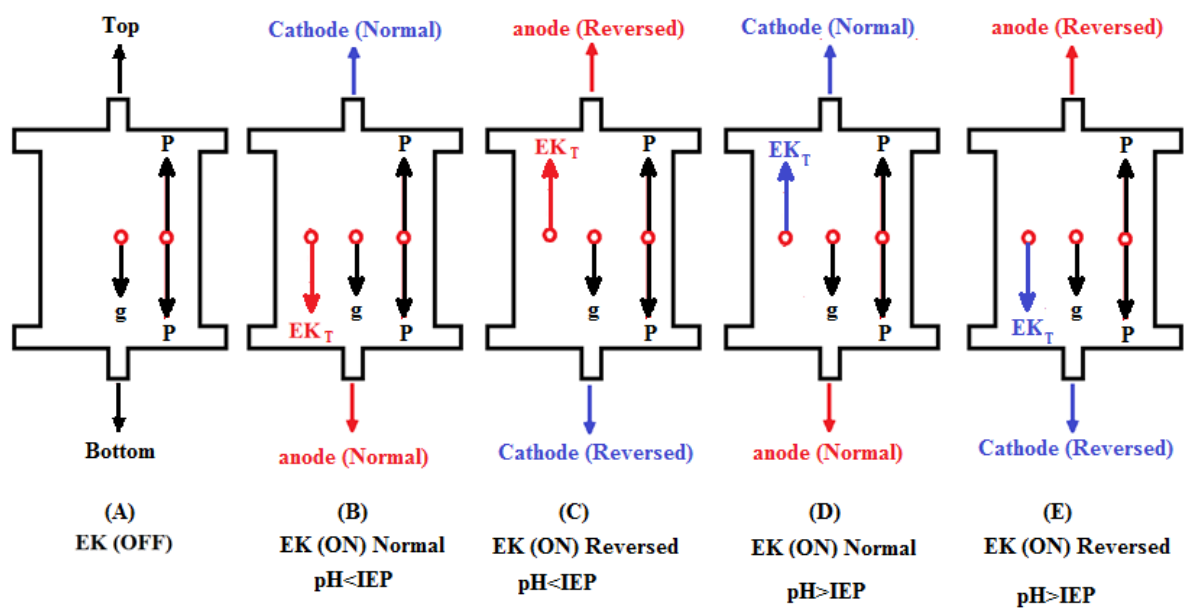


Figure 5. Forces affecting water movement inside the experimental cell under different orientations; A. Control situation, B. Normal situation and acidic medium when pH<IEP, C. Reversed situation and acidic medium when pH<IEP, D. Normal situation and basic medium when pH>IEP, and E. Normal situation and basic medium when pH>IEP.

Discharged filtrate movement in food materials under application of electrokinetics

H. Iessa, K. Christensen, J.A. Hall and C.J. Seal

- Dewatering of foods by electrokinetics is investigated.
- Water flow direction is determined by pH and lowest conductivity point (LCP).
- In acidic foods (e.g. orange juice), $\text{pH/LCP} < 1$; water moves to the anode.
- In alkaline foods (e.g. malt extract), $\text{pH/LCP} > 1$; water moves to the cathode.
- Controlling pH and electrode orientation maximises dewatering efficiency.